RIAP BULLETIN

Volume 2, Number 1 **January—March 1995**

THE TUNGUSKA METEORITE: A DEAD-LOCK OR THE START OF A NEW STAGE OF INQUIRY? — Part II

N.V.Vasilyev

6. On radioactivity in the region of the Tunguska catastrophe

The hypothesis of the nuclear nature of the Tunguska explosion was tested by search for radionuclides of 1908 at the epicenter of the catastrophe and in the explosion products in the area of the supposed dispersion train [98–101]. The results of these researches may be summarized as follows:

1. Radioactivity at the epicenter of the Tunguska explosion is within the range of fluctuations of the present background. At the same time, its magnitude is somewhat higher at the epicenter that at the periphery of the region. Most radionuclides are concentrated in the upper horizons of the soil and peat, and are accumulated from global fallout after nuclear tests and technogeneous catastrophes.

2. The vertical distribution of radionuclides in the soil and peat gives, as a rule, no reason for suggestion on fallout of technogeneous radionuclides before 1945. The only exception is a result of layer-by-layer radiometry of sphagnum peat in the region of Vanavara (1960) [98] where a second maximum of radionuclide concentration was discovered at the depth of 35 cm. This effect was not studied in detail and it is not known which radionuclides were responsible for it.

3. Investigation of the isotopic composition of inert gases, conserved in rocks near the epicenter did not reveal any peculiarities which could be explained by the action of neutron irradiation on the natural environment at the epicenter [101].

4. Analysis of ^{14}C content in the rings of the trees which survived the year 1908, revealed its reliable excess over background values for the ring of 1909, which could be expected if $^{14}CO_2$ content was abnormally high in the summer of 1908. The effect is of a global character and has been traced both in the region of the Tunguska catastrophe [102] and outside [103]. Usually it is explained by interference in the years 1908–1909 of two solar maxima, viz. the 11-year and 100-year ones [102]. However such an interpretation does not explain the causes of the patchy character of the effect at the epicenter of the Tunguska catastrophe [104]. The "solar" nature of the effect would be proved if it were detected for other similar periods as well. But such a work, as far as we know, has yet to be performed.

Thus, the results of search for radioactivity in the region of the Tunguska catastrophe are in terms of the nuclear hypothesis negative. It should be noted, however, that search for traces of radionuclide fallout half a century after a nuclear explosion in the atmosphere is a challenging task (especially taking into account the present technogeneous contaminations). Therefore, this negative result cannot be considered as final.

Along with attempts to look for radionuclides retained, as was expected, in the region of the Tunguska catastrophe, some efforts were made to find their traces by indirect methods as well. First and foremost, there were studied variations of thermoluminescent properties of minerals in the catastrophic area. It is well known that shifts in the intensity of thermoluminescence are reliable, even if indirect, indication of exposure of minerals to ionizing radiation. This method was successfully used, in particular, in an attempt to determine the level of radioactivity at the epicenter of the nuclear explosion over Hiroshima some years after the event [105]. Similar works were carried out in the area of the Tunguska catastrophe epicenter [106; 107]. Their results suggest that background characteristics of thermoluminescent minerals in this re-

CONTENTS

Published Quarterly by Research Institute on Anomalous Phenomena
P.O.Box 4684, 310022 Kharkov-22, UKRAINE
Distributed Free Among RIAP Fellows and Donators

gion were distorted by two opposing factors which counteracted each other. The first of them *reduced* thermoluminescent properties of minerals in the immediate vicinity of the epicenter. Judging from similarity between the contours of this zone and the area of the radiant burn of the trees, the effect was generated by the light flash. This seems plausible, since annealing of minerals leads to decrease in their thermoluminescent properties and even to loss of them [108]. But it remains unclear why this effect manifested itself only in the area of the light flash, and not in the entire zone of the forest fire.

In parallel with the first factor there operated, however, another one, which *intensified* thermoluminescence of the minerals. This factor was at its maximum in an area tending to the projection of the TSB trajectory. Its nature has not been established, but the contribution of ionizing radiation is a possibility. It should be added that the peak of abnormally high thermoluminescence correlates with the so-called "blind spot" of the burn — that is, the zone of minimal thermal effects of the Tunguska catastrophe which is localized in the immediate vicinity of the projection of the TSB path [107].

So, the total combination of data relative to the possible "nuclear trace" of the Tunguska explosion does not allow to reject its existence. If the explosion was nuclear indeed, the geomagnetic effect can also be explained, since its time lag is in good accordance with the time the cloud of the explosion products would take to rise to mesosphere [56].

7. Ecological consequences of the Tunguska catastrophe

Ecological consequences of the Tunguska catastrophe have been studied during the last 30+ years. They can be divided into two main types.

The first of them is the remarkably soon revival of the taiga after the catastrophe, as well as accelerated growth of young trees and those which survived the event [49–51]. This effect covers a vast territory, it correlates with the TSB trajectory [51] and does not necessarily fall within the area of forest leveling. The effect is observed in all wood species which are present in the region, tending (for the 2nd and 3rd post-catastrophic generations of pine trees) to concentrate toward the projection of the TSB path [109]. There are two traditional viewpoints on the nature of the effect.

According to the first one, the soon revival and accelerated growth of the forest are due to some general results of the Tunguska explosion — such as better light and thermal conditions in the area after leveling of the so many trees, as well as enrichment of the soil with microelements as a result of the forest fire [110]. This point of view is not groundless, but it does not explain the following facts:

1. an evident correlation of the effect with the projection of the TSB trajectory;
2. discrepancy between the zones of the accelerated growth of saplings and the areas of the forest fall and forest fire of 1908.

According to the other conception, the stimulating effect of the Tunguska explosion is due to enrichment of poor soil of the region with *cosmogeneous* microelements. Modeling experiments evidencethat extracts of the soils from the region enriched with rare-earth elements (REs) can in fact stimulate germination of pine seeds, as well as the seeds of some other plants [111]. But rare earths are outside the classical set of cosmogeneous microelements.

The question has not been finally settled, but the effect cannot probably be explained just by conventional factors [112].

The second type of ecological consequences of the Tunguska catastrophe includes its genetic impact. Linear increments of the Tunguska pine trees were processed with an algorithm discriminating the contributions of genotypic and phenotypic variations. This work revealed that the frequency of mutations in these pines has sharply increased. Again, as many other effects of the Tunguska catastrophe, its genetic impact is of a patchy character, concentrating toward the epicentral area and the "corridor" of the TSB trajectory. The thermal influence of the forest fire could hardly be in this case of any importance, since the contours of the areas of the mutagenic effect, forest fire, and forest fall are totally different. The nature of the mutagenic factor remains unknown, but the contribution of a powerful electromagnetic pulse which seems to have accompanied the flight and explosion of the TSB [115; 116] is not improbable. The mutagenic action of electromagnetic disturbances has been ascertained in modeling experiments [117].

There is little information on genetic consequences of the Tunguska explosion for other biological species in the region. However, morphometric peculiarities of certain species of ants living in the epicentral area appear to be worthy of attention in this respect [118]. Besides, a rare mutation in Rh-antigen has reportedly arisen among the natives of the region (the Evenks) in the 1910-s [119]. This mutation originated in Strelka–Chunya, one of the settlements nearest to the site of the Tunguska explosion. These materials are certainly deserving of more attention.

It is pertinent to add that medico-ecological examination of the state of health of native inhabitants of Evenkiya reveals population-genetic effects similar to those observed in the regions affected by nuclear weapon tests (the Altai Territory, the Lower Ob', the areas around the coast of the Kara Sea) [120–122]. This refers to oncological morbidity of the population, some peculiarities of its immunity status and circulation of oncogenic viruses.

8.On the substance of the Tunguska meteorite

Up to now, investigators have not a milligram of a substance which can be positively identified with the substance of the Tunguska "meteorite". However, some data appear to hold promise in this respect.

The diligent search for large fragments of the Tunguska space body which had begun in the late

1920-s ended by 1962 with a totally negative result. There were found no traces of astroblemes; as for geomorphological formations which were taken for meteorite craters, these proved to be of purely terrestrial origin (swamps, lakes, thermokarst holes, etc.) [35; 36; 123]. Attempts to find fragments of the meteorite through rough mineralogical analyses of soil, as well as with the help of magnetometers, mine detectors, etc., also failed [1; 37; 123]. As a result, beginning from the 60-s, strategy of the search for the TSB substance was radically altered, being since then mainly aimed at search for and analysis of finely-dispersed space material [126; 127; 128].

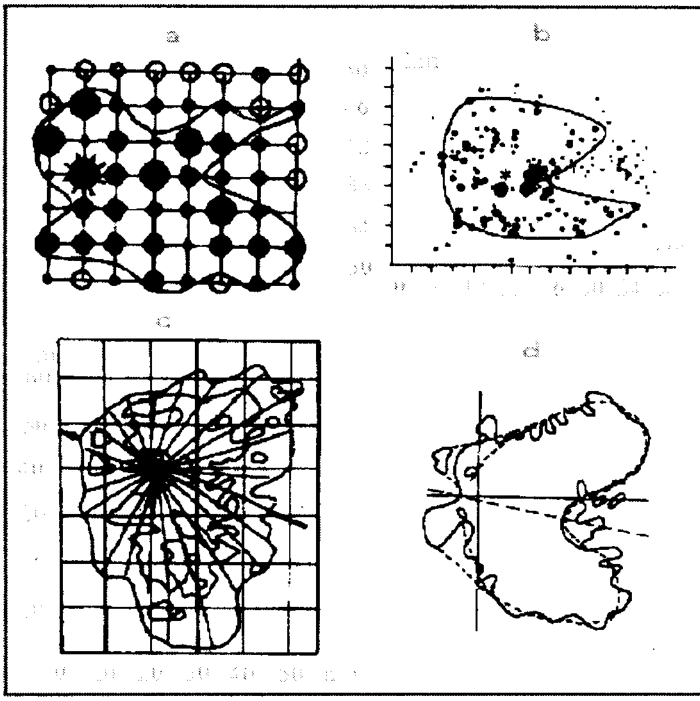


Fig. 2. The traces of the Tunguska explosion on the Earth's surface which are "butterfly-like" in shape:
a) zone of accelerated growth of young pine trees;
b) zone of the radiant burn of trees;
c) isodynamic curves of the shock wave, based on analysis of the vector structure of the fallen forest [10];
d) zone of forest leveling, reconstructed from aerial photographs of the taiga (according to D.F.Anfinogenov, 1966).

During the subsequent 30+ years a number of cosmochemical, geochemical, analytical and other techniques were used in the region of the Tunguska catastrophe. The principal results of these works can be summarized as follows:

1. Small amount of finely-dispersed silicate and magnetite space material is present in soil and peat in the region of the Tunguska explosion and around it [126–134]. However, there is no direct evidence it has anything to do with the Tunguska space body. On the contrary, there is good reason to believe we are dealing here just with fluctuations of the background fall of space dust [135].

2. Information on the iridium anomaly in the Antarctic ice and Tunguska peat, dated back to 1908 [136; 137] rests on isolated findings, being to some extent contradictory [138] and requiring further verification.

3. Increased concentration of silicate microspherules enriched with copper, zinc, gold and some other volatile and chalcophile elements is found in the "catastrophic" layers of peat and wood resin in a number of points of the region [139; 140]. Cosmogeneous nature of these anomalies is probable but not proven; they should be differentiated from aerosols produced by burning of peat and (possibly) wood [141], as well as from volcanic ash [142].

4. There have been revealed in the "catastrophic" layers of peat, both at the epicenter of the Tunguska explosion and in the zone of the supposed dispersion train of its products, substantial shifts in isotopic compositions of carbon (toward its heavier isotopes), hydrogen (toward the lighter ones) [45; 143] and lead [144]. According to E.M.Kolesnikov, these shifts are due to dispersed substance of a space body of the approximate composition of carbonaceous chondrite. The principal importance of these data to the Tunguska studies is evident, but to finally interpret them, it would be essential to analyze samples of peat taken in a control area having similar natural and climatic conditions, particularly as regards permafrost.

5. A number of local geochemical anomalies were discovered at the epicenter of the Tunguska catastrophe, although their association with the TSB requires further investigations. This is, first of all, the rare-earth (primarily ytterbium) anomaly. Concentration of the latter element in soil, as well as in the "catastrophic" peat layers is abnormally high [125; 145]. The ytterbium content reaches its peak in the point of intersection of the extension of the TSB trajectory (provided that its slope was 40°) with the Earth's surface. Increased concentration of REs occurs mainly in the upper (i.e. recent) layers of soil, and not in its deeper ones, close to the substratum [146]. Along with the quantitative shifts, there is observed in the zone of the effect also a drastic change in the REs ratio.

Although rare earths are not considered as evidently cosmogeneous elements, there are two findings deserving of attention in this respect.

In the early 60-s, a team of scientists examined the chemical composition of aerosols in different layers of ice on the Antarctic shelf. The chemical composition of all particles found in the taken core samples is given in Ref. [147]. As these data indicate, there was present in the layer dated back to 1908 an anomalous particle enriched with REs. Its origin remained a mystery (an accidental contamination was suggested). Likewise, during the American–Swedish experiment in Kiruna [148], aimed at

collection of space material forming condensation nuclei of silvery clouds, there were discovered particles containing rare earths, in particular ytterbium. These data were also explained away as a contamination of mesosphere with products of nuclear tests and were not discussed in the literature any longer. It is apparent, however, that the issue has not been closed, and the RE anomaly at the epicenter of the Tunguska explosion needs further examination.

Thus, the key to the solution of the Tunguska problem — that is, determination of the TSB elemental as well as isotopic composition — is not yet at hand, and this line of inquiry is open to many surprises.

9. On the geometry of the Tunguska catastrophe effects

A distinguishing feature of the "Tunguska effects" is their peculiar geometrical structure. As illustrated in Fig. 2, outlines of the areas of the so diverse phenomena as forest fall, radiant burn of trees, accelerated growth of young trees (and also, as was established subsequently, thermoluminescence of the mineral component of the soil) have much in common. In particular, the latter three effects have a "blind spot" in the ENE sector of the catastrophe region. The outline of the epicentral area that was revealed with the help of spectrozonal satellite photography (the so-called "light spot" [149]) is very similar to those in Fig. 2 (a, b). There is an impression that the ENE sector of the catastrophe region was screened from the thermal influence of the flash, but exposed to the hard radiation of the Tunguska explosion. The nature of the relation between the structure of the radiant burn area and the blast wave of the explosion also remains obscure. It can be considered as an evidence in favour of anisotropy of the explosion fireball.

10. On internal inconsistency of the traditional models of the Tunguska phenomenon

Beginning from the 60-s, proponents of traditional TSB models were pinning their main hopes on the cometary hypothesis that had been put forward in the 30-s by I.S.Astapovich [5] and F.Whipple [12] and later developed by V.G.Fesenkov [151; 152]. It was suggested that unlike the asteroidal version the cometary hypothesis could explain in a conclusive way the main peculiarities of the Tunguska event distinguishing it from other impact phenomena, namely:

1. the overground character of the explosion;
2. the lack of an astrobleme, as well as any trace of a large-scale fallout of meteorite matter;
3. the set of the atmospheric optical anomalies accompanying the Tunguska explosion.

Indeed, the cometary hypothesis have had rather a favorable effect on the progress of the Tunguska studies. In its framework there were made attempts to calculate the main parameters of the TSB (its velocity, mass, energy, strength characteristics, the slope of the "meteorite" path, etc.), as well as to describe the mechanism of the TSB destruction, and so on. Later, however, results of further studies have complicated the situation which seems to approach at present a critical point. Some obstacles which the cometary hypothesis ran into have been discussed above. It should be added that the authors of some theoretical models proceeded from the assumption of a low (of the order of 10^{-2} g cm^{-3} [153]), or even super-low (10^{-3} g cm^{-3} [154]) density of the Tunguska space body. Direct probing of Halley's comet [155] has shown, however, that the real density of cometary ice is about 1 g cm^{-3}. Consequently, the models of the TSB as a "super-loose lump of cosmic snow" or a "gigantic cosmic snowflake" should be rejected.

These failures did not affect, however, the "core" of the cometary hypothesis, since most of its supporters proceeded from more realistic estimates of the cometary ice density, assuming it to be equal to 1 g cm^{-3}. But recently there appeared serious works casting doubt on the very fundamentals of this hypothesis. We mean, first of all, the detailed calculations, made by Z.Sekanina [157], who came to the conclusion that due to the strength characteristics of the comet nucleus, it would have had to disintegrate at a much higher altitude than it happened in reality. Then, the authors of paper [158], using methods of mathematical simulation, have come to the conclusion that gigantic carbonaceous chondrites have to disintegrate at an altitude of 30 km; a circumstantial argument in favour of this inference being the explosion of the Revelstoke carbonaceous chondrite [159], as well as high-altitude explosions of loose meteorites, confirmed by aerospace methods. Since the chemical composition of the Tunguska "meteorite" in its dominant conventional models is identical to that of a comet nucleus, or to a carbonaceous chondrite, verification of works [157; 158] would be of crucial importance to the Tunguska problem.

Both Z.Sekanina [157] and C.Chyba et al. [158] arrived at the conclusion that the TSB should be classified as a stony asteroid. An iron meteorite as large as this would have reached the Earth's surface and formed an astrobleme; a comet nucleus or a carbonaceous chondrite would have disintegrated at a much higher altitude than the Tunguska body did. But if this is the case, then the question of the TSB substance reappears. A number of problems remain unsolved — such as, for example, isotopic anomalies in the "catastrophic" layers of sphagnum bogs at the epicenter, as well as increased concentration of volatile and chalcophile elements therein. Although the conclusions of works [157] and [158] are in agreement with paper [161] demonstrating that a stony asteroid of a mass about 100,000 metric tons, dispersed over the central part of the Tunguska catastrophe region, would not affect considerably the level of the background fall of space matter, it is true only for a uniform (and not a patchy) distribution of the asteroid substance over the area. But the latter is at least not evident. Besides, return to the stony

asteroid model would require a re-explanation of the 1908 atmospheric optical anomalies which were for a long time assumed to be due to penetration of the "Tunguska comet" tail into the atmosphere. There is, therefore, an impression that after the 40 years of the post-war studies the problem of the Tunguska "meteorite" is now returning to its origin, that is to evident discrepancy between the existing paradigm and a number of established facts.

11. On unconventional approaches to the problem of the Tunguska catastrophe

Non-traditional approaches to the Tunguska "meteorite" problem appeared soon after World War II. They can be subdivided into two categories.

One of them includes a variety of versions ignoring all the body of factual evidence and based in many cases on abstract or extremely subjective opinions. These are first of all attempts to explain the Tunguska phenomenon by purely terrestrial causes: explosion of a methane cloud accumulated over the marsh, a ball lightning, etc. These hypotheses cannot be subject to serious discussion.

The hypothesis that the Tunguska "meteorite" was a microscopic black hole [55] is also utterly subjective and does not conform to the facts.

The second category involves serious, even if not proved, conceptions — such as the hypothesis of the antimatter nature of the TSB [54]. The experimental results contradict this hypothesis [101], but the existence of antimatter meteor streams cannot be totally denied, particularly in view of the data of work [162]. Still, this cosmologically important question can hardly be closely associated with the problem under discussion.

It is also worthwhile to consider the "plasmoid" hypothesis proposed in Ref. [56], though the plausibility of stable existence of "solar plasmoids" and "energophores" in space is also disputable. Still more disputable is the question of similarity of effects, that can arise from penetration of such objects into the atmosphere, with the Tunguska phenomenon.

Finally, due attention should be given to the hypothesis of the technogeneous nature of the TSB [58; 59; 163; 167]. Actually, there are no direct proofs of it. However, if the meteor astronomy episodes are estimated as to the probability of contacts with extraterrestrial technogeneous objects, the Tunguska phenomenon will be undoubtedly in the first place. The numerous strange features of its image, complexity, various incongruities, and obvious impossibility to reduce it to simple models assume, with high probability, its unconventional origin. In this connection, it seems reasonable to modify the strategy of the subsequent study of the problem.

At present the study of the problem has reached a phase in which it becomes possible to rigorously formulate some principal questions, which, if resolved, can restrict the spectrum of acceptable TSB models. Primarily, these are the following closely related questions:

1. Can the Tunguska "explosion" be explained as a result of destruction of comet ice lumps or a meteoroid similar to carbonaceous chondrites at an altitude of 5–8 km? Who is right — Sekanina [157] and Chyba [158] denying such a possibility, or the authors of Refs. [66; 67; 71; 72; 75; 90] seeking to prove it? If the former are right, then it becomes imperative to revise a large number of calculations dealing with the mechanism of destruction of the Tunguska "meteorite" that have been published since 1963. It is also necessary to re-explain the isotopic and elemental anomalies at the epicenter of the catastrophe, and re-interpret the atmospheric optical anomalies of the summer of 1908.

2. In view of the importance of the quantitative estimation of the silicate aerosol which could fall at the epicenter of the Tunguska explosion and on its dispersion train, provided that the TSB was really a stony asteroid, is really unambiguous the conclusion of the author of work [161] on the explosion of a stone meteorite? It seems quite necessary to make more calculations with due regard to factual data on powerful explosions, published after 1975.

3. What is the nature of the isotopic and elemental anomalies in peat layers and wood resin dated 1908 [43–47; 139; 143; 144; 165; 166]? Are they due to precipitation of remnants of the TSB or to some other processes? If indeed isotope shifts and increased concentrations of volatile and chalcophile elements dated 1908 in these natural objects are due to some material of the TSB, then in this case, firstly, the paradox of the absence of space matter in the area of the catastrophe comparable with the scale of the phenomenon is eliminated, and secondly, in terms of the traditional hypotheses this is only possible if the TSB was the nucleus of a comet or an object similar to carbonaceous chondrites in the composition [45]. Hence, explanation of the nature of the said elemental and isotopic anomalies contains a serious, but maybe the last possibility of explaining the Tunguska phenomenon in terms of the traditional concepts. Thus, it appears utterly important to make check investigations in control areas that are not associated with the Tunguska catastrophe. There are two reasons for this:

First, the peat layer of 1908 practically coincides with the boundary between permafrost and thawing layers of peat. The problem of isotopic selection in such borderline media has been posed but not resolved. Thus, it is appropriate to carry out check analyses in background permafrost areas.

Second, the Tunguska catastrophe occurred between major eruptions of two volcanoes, viz. Ksudach on Kamchatka in 1907 and Katmai on the Aleutian Islands in 1912. Both caused global atmospheric pollution with volcanic ash which fell out in 1908 even in Germany [22]. Therefore, to correctly interpret the above elemental and isotopic anomalies it is essential to differentiate them

from the effects observed in the areas of major fall-out of volcanic ash.

4. Can the atmospheric optical anomalies of 1908 be due to transport of TSB matter at all (the material of a stony asteroid in particular) from the site of the "explosion" by stratospheric winds?

5. What is the nature of the WNW segment of the "corridor" of axially symmetric deviations of forest fall vectors from the dominating radial pattern, and can it be due to anything else than the trace of the ricochet of the part of the TSB that survived the "explosion", in terms of the traditional models?

6. Is it possible to resolve the contradiction between the TSB trajectory as defined from evidences of the Angara eye-witnesses and the direction of flight of the body as suggested by the vector pattern of the forest fall?

Unambiguous comprehensive solution of the above problems will favour choice between the traditional and nontraditional hypotheses. It would be now too early to predict the conclusion, but the ability to pose the problem in this way is really a serious achievement in the history of the development of the Tunguska problem.

12. On the necessity to protect the Tunguska catastrophe area

The zone of the Tunguska catastrophe is a unique area on the Earth, where the humanity has become a witness of a large-scale space catastrophe. Even this single fact, irrespective of the nature of this event, calls for protection of this area, for further investigations.

If it turns out that the TSB was of extraterrestrial artificial origin indeed, the necessity of protection of the area will increase immeasurably.

It seems evident that certain consequences of the Tunguska catastrophe, primarily ecological effects, will manifest themselves for years, maybe decades or even centuries. Such are in particular population-genetic effects of the catastrophe. In view of the important part played by impact phenomena in the evolution of the terrestrial biosphere [166], it is utterly important to take immediate measures to set up a nature reserve in this area.

What alarm is that the explosion of a space body of unknown origin with the TNT equivalent of the order of 40 MT raised neither concern nor interest of the civilized mankind. It is known that in 1902, on Martinique, evacuation of the population before the eruption of Mt.Pelee was postponed because of forthcoming municipal election. As a result, the population of the whole town of Saint-Pierre died, so that neither electors nor electees survived. Mankind must not repeat this error in the case of the Tunguska catastrophe which would be potentially much more imprudent: it is even hard to imagine what ecological, social and even political impacts can result from a new catastrophe similar to that of the year 1908, if it occurs not over the practically unpopulated Siberian taiga, but over industrial areas of Europe or the United States of America.

References

98. Kirichenko L.V., Grechushkina M.P., in: *Problema Tungusskogo meteorita*. Tomsk: Izdatelstvo Tomskogo Universiteta, 1963, p. 139–152.

99. Kirichenko L.V., in: *Problemy meteoritiki*. Novosibirsk: Nauka, 1975, p. 88–101.

100. Stadolko I., in: *Problema Tungusskogo meteorita*. Kharkov. In press.

101. Kolesnikov E.M., Lavrukhina A.K., Fisenko A.V., *Geokhimiya*, 1973, No. 8, p. 1115–1121.

102. Nesvetaylo V.D., Kovalyukh N.N., in: *Meteoritniye i meteorniye issledovaniya*. Novosibirsk: Nauka, 1983, p. 141–150.

103. Vinogradov A.P., Devirtz A.A., Dobkina E.I., *Doklady AN SSSR*, 1966, Vol. 168, No. 4, p. 900–903.

104. Firsov L.V., Zhuravlev V.K., Panychev V.A., in: *Meteoritniye issledovaniya v Sibiri*. Novosibirsk: Nauka, 1984, p. 67–77.

105. Daniels F., Boyd Ch., Saunders D., *Uspekhi Fizicheskikh Nauk*, 1953, Vol. 51, No. 2, p. 271–286.

106. Vasilenko V.B., Demin D.V., Zhuravlev V.K., in: *Problema Tungusskogo meteorita*, Vol. 2. Tomsk: Izdatelstvo Tomskogo Universiteta, 1967, p. 227–231.

107. Bidyukov B.F., Krasavchikov V.O., Razum V.A., in: *Sledy kosmicheskikh vozdeystviy na Zemlyu*. Novosibirsk: Nauka, 1990, p. 88–107.

108. Morozov G.V. Opredeleniye otnositelnogo vozrasta antropogenovykh otlozheniy Ukrainy termolyuministsentnym metodom. Kiev: Naukova Dumka, 1968.

109. Vasilyev N.V., Batishcheva A.G., in: *Voprosy meteoritiki*. Tomsk: Izdatelstvo Tomskogo Universiteta, 1976, p. 149–160.

110. Drapkina G.I., Berezhnoy V.G., *Meteoritika*, 1964, Vol. 24, p. 162–169.

111. Kukharskaya L.K., Boyarkina A.P., et al., in: *Vzaimodeystviye meteoritnogo veshchestva s Zemley*. Novosibirsk: Nauka, 1980, p. 195–202.

112. Kolesnikov V.I. in: *Problema Tungusskogo meteorita*. Tomsk: Izdatelstvo Tomskogo Universiteta, 1963, p. 73–83.

113. Ivanov K.G., *Meteoritika*, 1961, Vol. 21, p. 46–48.

114. Plekhanov G.F., Kovalevskiy A.F., Zhuravlev V.K., Vasilyev N.V., *Geologiya i geofizika*, 1961, No. 6, p. 94–95.

115. Boyarkina A.P., Sidoras S.D., *Geologiya i geofizika*, 1974, No. 3, p. 79–84.

116. Sidoras S.D., Boyarkina A.P., in: *Voprosy meteoritiki*. Tomsk: Izdatelstvo Tomskogo Universiteta, 1976, p. 64–73.

117. Artamonov A.A., Artamonava L.N., in: *Problema Tungusskogo meteorita*. Kharkov. In press.

118. Vasilyev N.V., Dmitrienko V.K., Fedorova O.P., in: *Vzaimodeystviye meteoritnogo veshchestva s Zemley*. Novosibirsk: Nauka, 1980, p. 188–195.

119. Rychkov Yu.G., personal communication.

120. Potapov A.I. et al. (Eds.) Atlas zabolevayemosti zlokachestvennymi novoobrazovaniyami naseleniya Sibiri i Dalnego Vostoka. Tomsk: Izdatelstvo Tomskogo Universiteta, 1990.

121. Vasilyev N.V., Pisareva L.F., Podoplekin L.D. Osobennosti rasprostraneniya onkologicheskoy patologii u malochislennykh narodov Sibiri i Dalnego Vostoka. Tomsk: Izdatelstvo Tomskogo Universiteta, 1992.

122. Vasilyev N.V., in: *Sreda obitaniya i zdorovye naseleniya Sibiri*. In press.

123. Piavchenko N.I., *Priroda*, 1962, No. 8, p. 24–42.

124. Plekhanov G.F., *Meteoritika*, 1964, Vol. 24, p. 170–176.

125. Zhuravlev V.K., Demin D.V., Vronskiy B.I., et al., in: *Voprosy meteoritiki*. Tomsk: Izdatelstvo Tomskogo Universiteta, 1976, p. 99–111.

126. Florenskiy K.P., *Geokhimiya*, 1963, No.3, p. 284–296.

127. Florenskiy K.P., *Geokhimiya*, 1962, No.2, p. 187–189.

128. Florenskiy K.P., Ivanov A.V., Ilyin N.P., et al., *Geokhimiya*, 1968, No. 10, p. 1163–1173.

129. Vasilyev N.V., Ivanova G.M., L'vov Yu.A., *Priroda*, 1973, No.7, p. 99–101.

130. Vasilyev N.V., L'vov Yu.A., Vronskiy V.I., et al., *Meteoritika*, 1973, Vol. 32, p. 141-146.

131. Vasilyev N.V., L'vov Yu.A., Ivanova G.M., et al., in: *Problemy kosmicheskoy fiziki*, Kiev: Vishcha shkola, 1974, Vol. 9, p. 79–83.

132. Vasilyev N.V., Ivanova G.M., L'vov Yu.A., *Priroda*, 1973, No.7, p. 99–101.

133. Vasilyev N.V., L'vov Yu.A., Grishin Yu.A., et al., in: *Problemy kosmokhimii*, Kiev: Naukova Dumka, 1974, p. 60–69.

134. Jehanno C., Boclet D., Dunon J., Robin E., Rocchia R., *Lunar and Planetary Science. Conf. XX. Abstracts*. Houston, Texas, 1986, p. 458–459.

135. Ivanova G.M., L'vov Yu.A., Vasilyev N.V., et al., Vypadeniye kosmicheskogo veshchestva na poverkhnost Zemli. Tomsk, Izdatelstvo Tomskogo Universiteta, 1975.

136. Ganapathy R., *Science*, 1983, Vol. 220, No. 4609, p. 1158–1161.

137. Korina M.I., Nazarov M.A., Barsukova L.D., et al., *Lunar and Planetary Science*, 1987, XVIII, p. 501–502.

138. Roccia R., Angelis M. de, Boclet D., et al., in: *Global Catastrophes in Earth History / Absracts of Conference*. Snowbird, Utah, 1988, p. 156–157.

139. Longo G., Serra R., Cecchini S., Galli M., *Planetary and Space Science*, 1994, Vol. 42, No. 2, p. 163–177.

140. Kolesnikov E.M., Liul' A.Yu., Ivanova G.M., *Astronomicheskiy vestnik*, 1977, Vol. XI, No. 4, p. 209–218.

141. Doroshin I.K., in: *Aktualniye voprosy meteoritiki v Sibiri*. Novosibirsk: Nauka, 1988, p. 31–40.

142. Boutron C., *J. of Geophys. Res.*, 1980, Vol. 85, p. 7426–7432.

143. Kolesnikov E., *Global Catastrophes in Earth History / Absracts of Conference*. Snowbird, Utah, 1988, p. 97–98.

144. Kolesnikov E.M., Shestakov G.I., *Geokhimiya*, 1979, No. 8, p. 1202–1211.

145. Levchenko M.A., Terentieva A.S., in: *Kosmicheskoye veshchestvo na Zemle*. Novosibirsk: Nauka, 1976, p. 16–19.

146. Dozmarov S.V., in: *Problema Tungusskogo meteorita*. Kharkov. In press.

147. Hodge P.W., Wright F.W., *J. of Geophys. Res.*, 1964, Vol. 60, No. 14, p. 2919–2931.

148. Hemenway C.L., Erkes J.W., Greenberg J.M.A.O., in: *COSPAR Space Research XIII*. Berlin. Akad. Verlag, 1973, p. 1121–1125.

149. Pasechnik I.P., Zotkin I.T., in: *Aktualniye voprosy meteoritiki v Sibiri*. Novosibirsk: Nauka, 1988, p. 248–251.

150. Vorob'ev V.A., Demin D.V., in: *Voprosy meteoritiki*. Tomsk: Izdatelstvo Tomskogo Universiteta, 1976, p. 58–63.

151. Fesenkov V.G., *Meteoritika*, 1961, Vol. 21, p. 4–14.

152. Fesenkov V.G., *Astronomicheskiy zhurnal*, 1961, Vol. 38, No. 4, p. 577–592.

153. Petrov G.A., Stulov V.P., *Zemlya i Vselennaya*, 1975, No. 4, p. 74–75.

154. Turco R.P., Toon O.B., Park C., et al., *Icarus*, 1982, Vol. 50, No. 1, p. 1–52.

155. Balabanov V.M., Moroz V.I., *Priroda*, 1986, No. 5, p. 1–17.

156. Grigorian S.S., *Doklady AN SSSR*, 1976, Vol. 231, No. 1, p. 57–60.

157. Sekanina Z., *Astronomical Journal*, 1983, Vol. 88, No. 1, p. 1382–1414.

158. Chyba C.F., Thomas P.J., Zahnle K.J., *Nature*, 1993, Vol. 361, p. 40–44.

159. Folinsbee R.E., Douglas J.A., Maxwell J.A., *Geochim. et Cosmochim. Acta*, 1967, Vol. 31, No. 10, p. 1625–1635.

160. Levin B.Yu., Bronshten V.A., *Astronomicheskiy vestnik*, 1985, Vol. 19, No. 4, p. 319–330.

161. Kirichenko L.V., in: *Problemy meteoritiki*. Novosibirsk: Nauka, 1975, p. 111–126.

162. Konstantinov B.P., Bredov M.M., Sokolov I.A., *Kosmicheskiye issledovaniya*, 1966, Vol. 4, No. 1, p. 66–73.

163. Kazantsev A.P., *Vokrug sveta*, 1946, No. 1, p. 39–73.

164. Boyarkina A.P., Vasilyev N.V., Meniavtseva T.A., et al., in: *Kosmicheskoye veshchestvo na Zemle*. Novosibirsk: Nauka, 1976, p. 8–15.

165. Alekseeva K.N., Smirnova A.V., Vasilyev N.V., et al., *Ibid.*, p. 19–24.

166. Zeylik B.S., Kazachevskiy I.V., Shevelev G.A. Meteoritnoye veshchestvo na mel-paleogenovom rubezhe i v meteoritnykh kraterakh. Novosibirsk: Nauka, 1990.

167. Rubtsov V.V., Ursul A.D. Problema vnezemnykh tsivilizatsiy. Kishinev: Shtiintsa, 1987.

UFOs ON THE MOON

A.V.Arkhipov

Introduction

There are two general reasons for the search for lunar analogs of terrestrial UFOs:

– the extraterrestrial hypothesis of the origin of UFOs [22];

– the existence or nonexistence of lunar UFOs could be a test for some other hypotheses too (natural atmospheric phenomena, balloons, celestial bodies, etc.)

Nevertheless, the lunar aspect of the UFO problem is still unexplored. Although many authors wrote about "UFOs on the Moon" (e.g. [8, p. 42–54; 12, p. 98–181; 13; 14, p. 138–145; 18; 20, p. 220–230; 21]), those attempts were rather superficial descriptions of individual cases (often doubtful), without any serious analysis and comparison with terrestrial cases.

During several years the author has been studying this problem as part of the SAAM project (Search for Alien Artifacts on the Moon) of the Research Institute on Anomalous Phenomena [2]. Some preliminary results of this inquiry are reported here.

Phenomenology and analogy

Only a part of reported terrestrial UFOs could be seen from the Moon through conventional telescopes. Apparently we could see some brightest "nocturnal lights" and largest "daylight discs" as moving or motionless transient bright (sometimes as dark) spots and dots. Similar phenomena are known as lunar transient phenomena (LTPs) [7;16]. LTPs are usually interpreted as dust or gas–dust clouds and electrical discharges [9;17]. But there are some types of LTPs, which find no acceptable interpretation. Such LTPs appear to be similar to terrestrial UFOs. Let me consider these types in some detail.

Fast moving objects (FMOs) appear as light dots (43 %) and strips (14 %), or dark formations (32 %) moving against the lunar disc and near it at the velocities from 10^{-3} to 1 degree per second during ≤ 1 minute [3]. From literature and the files of the RIAP LTP network, the author has compiled a catalogue of FMOs which had the starting and/or final points of their trajectories on the lunar disc. More than 39 such dots lie on one half of the disc (Fig. 1). Only 9 points are behind this zone. According to the binomial distribution the probability of such accidental asymmetry is only 7.6×10^{-6} [5]. Although the western (selenographic) half of the lunar disc is less popular among observers than the eastern one, FMOs are more often seen there. Thus, a considerable part of FMOs is really connected with the Moon. Apparently, the contribution of terrestrial bodies and meteors is insignificant. About 14% of FMOs moved along bent, wound, or broken UFO-like trajectories. Their velocities (~10^2 km/s) and accelerations

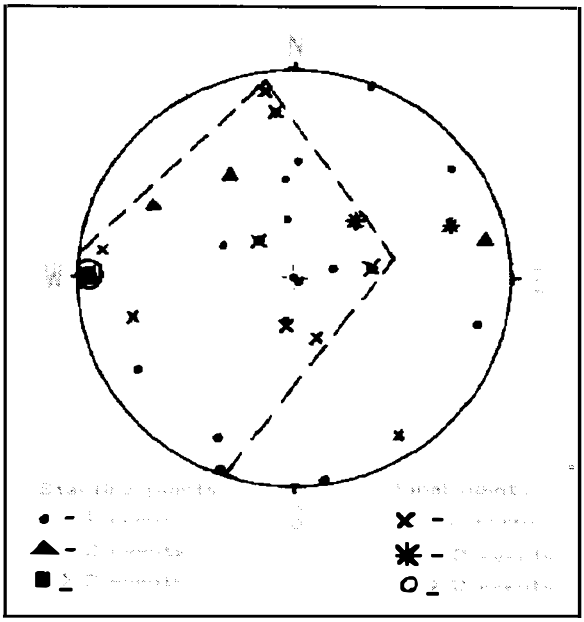


Fig. 1. Distribution of the starting and final points of trajectories of FMOs on the lunar disc. The numbers of the events are marked by different symbols. The dashed line bounds the zone of increased occurence of FMOs (50 % of the lunar disc area) [5].

(~10^4 g) are similar to those of UFOs observed near the Earth.

Nocturnal lights (NLs) appear as follows:

(a) *Motionless light dots* of quasiconstant stellar magnitude (e.g. cases Nos. 74, 140, 151, 153, 312, 1204, 1206, 1229 of [7]). Sometimes the observer noted illumination of the lunar surface around such dots. The cosmic rays and solar radiation cannot excite observable luminescence on the dark side of the Moon [16]. A gas cloud cannot exist as a point object during periods of 10 minutes to 2 hours of the NLs lifetime. It is almost unlikely that electrical discharges in a dust–gas cloud can give a luminescence of quasiconstant magnitude during such a long time.

(b) *Searchlight phenomena:* super-bright light dots seen by a naked eye (e.g. cases Nos. 6, 7, 9, 18, 257 of [7]); illuminated streaks on the lunar surface (cases Nos. 17, 20, 94, 102, 174, 192, 884 of [7]); numerous compact luminous spots on the surface (illumination by an unseen source of light?).

All these effects can be found, for example, in the description of the famous radar-visual UFO of September 7, 1984, seen over the USSR [11, p. 27].

Reflections from flat mirrors (RFMs) usually appear as star-like phenomena of 20–60 min. duration on the day side of the Moon (e.g. cases Nos. 50, 738, 739, 745, 1198 of [7]). It is unlikely that such

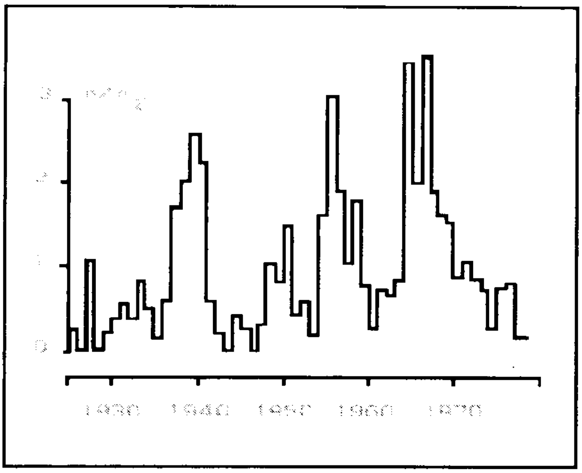


Fig. 2. Waves of LTP reports according to [7], where n is the annual number of reports and n_E the exponential trend of this number. Reports of the Lunar International Observers Network activated only during Apollo missions are omitted.

bright dots are reflections from lunar rocks. The very old age of the craters which showed RFMs, together with the rate of meteorite erosion of possible natural lunar mirrors, contradict this assumption [1]. An ideal mirror, observable from the Earth, must be of $> 0.1\ m^2$ area [15]. But "windows" and smooth surfaces are typical of UFO reports [11; 19]. Incidentally, moving mirrors could explain star-like phenomena of short duration ($\leq$ 20 min.) and series of point flashes (e.g. cases Nos. 1262, 1327 of [7]).

Moreover, LTPs demonstrate the same statistical properties as UFOs. Indeed, LTPs as well as UFOs are more often observed near the terminator [6, 10]. The typical duration of a UFO or LTP observation is about 10 minutes [7; 10]. The "waves of reports" are a well known property of the UFO phenomenon [19]. The stream of LTP reports demonstrates the wave temporal variations as well. If the exponential trend of the reports frequency [7] is removed, then the LTP waves of 1937–40, 1954–56, and 1964–67 years become evident (Fig. 2). By the way, the terrestrial UFO waves of 1954 and 1967 seem to be intriguing analogs to the LTP waves [10; 19].

Hints at intelligence

It is well known that behavior of UFOs not infrequently appears intelligent. These objects perform diverse manoeuvres and manipulations by lights, display interest in human activities, as well as respond defensively to various external influences [11]. LTPs also demonstrate what can be called intelligent or quasi-intelligent behavior. The "invasions" of Earth's vehicles to certain lunar regions stimulate statistically significant, real, temporary increase in the probability of LTPs emergence there (Fig. 3). For example, only one LTP (case No. 393 of [7]) was observed in Mare Tranquillitatis before the first probe impact of Ranger 6 on February 2,

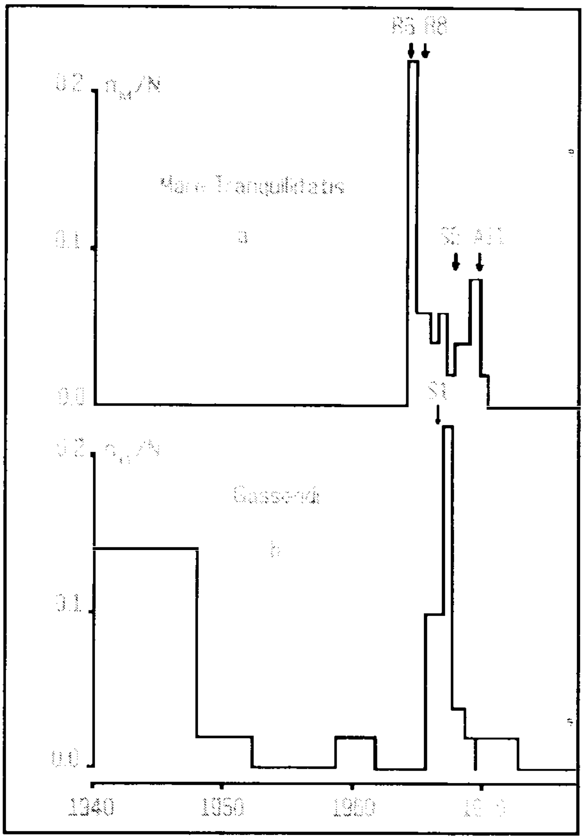


Fig. 3. Numbers of LTP events observed in Mare Tranquillitatis (n_M) and the Gassendi crater (n_G) in the ratio to their total number (N) [7]. Every step on the plots includes 50 LTPs observed on the whole lunar disc. The arrows point to the dates of invasions of space vehicles which landed in these regions (R – Ranger; S – Surveyor; A – Apollo).

1964, about 50 km south of the Ross crater, in the northern part of the Sea. Only several hours after the impact the 100 × 100 km zone east of Ross became one of the most LTP-active regions on the Moon up to September 25, 1969 (Fig. 4). The second LTP-zone appeared between the Sabine and Maskelyne craters around the impact site of Ranger 8 and landing sites of Surveyor 5 and Apollo 11. About 7.7 % of current LTPs belonged to this Mare in 1964–69, but 0.1 % only at other times. After the cessation of invasions in the Sea, the LTP activity vanished there. It is scarcely likely that the observers were especially interested in the landing sites. The LTP-zone near Ross existed for 5 years while 16 probes landed in other sites. Nevertheless, the LTP activity in the zone was not noticed when Apollo 17 landed on December 11, 1972, 370 km from Ross. Although the Ross D crater is recommended for LTP patrol, at present reports about transient lunar events there are very rare. In addition, the landings in Mare Foecunditatis, Mare Imbrium, Mare Serentitatis, and Oceanus Procellarum, were not accompanied by significant increase in LTP-activity in these regions. The exploration of Mare Imbrium in 1959–71 even

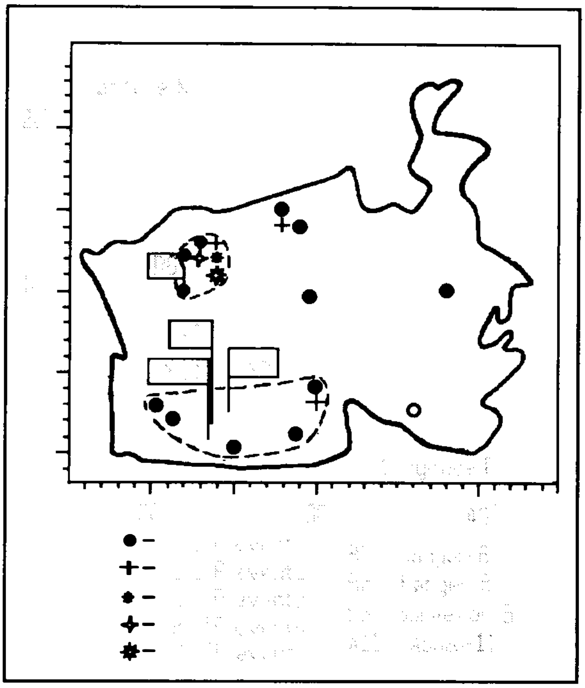


Fig. 4. Spatial distributions of sites of LTPs [7] and landings in Mare Tranquillitatis, where the solid curve is the Mare border, dashed curves are the borders of LTP-zones, the only LTP that was observed there before 1964 is marked by a small circle.

coincided with a temporary decrease of the LTP-activity of Mt. Pico in that area in 1955–71 [7].

Therefore, the "Invasion Effect" seems to be quite real. Some other manifestations of this effect and their analysis can be found in Refs. [4;5].

Conclusions

1. There is significant similarity between the UFO and LTP phenomena. At least some LTPs appear to be lunar analogs of UFOs observed near the Earth.
2. Apparently, UFOs are not an atmospheric or psychological phenomenon because they have been seen by competent observers in vacuum.
3. It is reasonable to search for physical traces of UFO landings on the lunar surface.
4. It is necessary to study interaction with UFOs as a risk factor for space missions to the Moon.

References

1. Arkhipov A.V. The Moon as an Attractor of Alien Artifacts.—*Selenology*, 1993, Vol. 12, No. 1, p. 6–8.
2. Arkhipov A.V. On the Importance of Nonclassical SETI.—*The Observatory*, 1993, Vol. 113, No. 1117, p. 306–307.
3. Arkhipov A.V. Moving "objects" on the Moon.—*Zemlya i Vselennaya*, 1994, No. 1, p. 86–91 (in Russian).
4. Arkhipov A.V. "Invasion Effect" on the moon.—*Selenology*, 1994, Vol. 13, No. 1, p. 9–11.
5. Arkhipov A.V. The Problem of the Search for Intelligent Life on the Moon. Institute of Radio Astronomy of the Ukrainian Acad. Sci. Preprint No. 70. Kharkov: IRA, 1994 (in Russian).
6. Cameron W.S. Lunar Transient Phenomena (LTP): manifestation, site distribution, correlations and possible causes.—*Physics of the Earth and Planetary Interiors*, 1977, Vol. 14, No. 2, p. 194–216.
7. Cameron W.S. Lunar Transient Phenomena Catalog NSSDC/ WDC-A-R&S 78-03, Greenbelt: NASA, 1978.
8. Drake W.R. Messengers from the Stars. London: Sphere Books, 1977.
9. Geake J.E., Mills A.A. Possible physical processes causing transient lunar events.—*Physics of the Earth and Planetary Interiors*, 1977, Vol. 14, No. 3, p. 299–320.
10. Gindilis L.M., Men'kov D.A., Petrovskaya I.P. Observations of Anomalous Atmospheric Phenomena in the USSR: A Statistical Analysis. Institute of Space Research. Preprint No. 473. Moscow, 1979 (in Russian).
11. Hesemann M. UFOs: Die Beweise. Eine Dokumentation. Muenchen: Verlag Michael Hesemann, 1991.
12. Jessup M.K. The Expanding Case for the UFO. London: Arco Publication, 1957.
13. Leonard H. Somebody Else Is On the Moon. New York: Pocket Books, 1976.
14. Leslie D., Adamski G. Flying Saucers Have Landed. London: Neville Spearman, 1970.
15. Liemohn H.B. Specular reflection on the Moon.—*Icarus*, 1968, Vol. 8, No. 2, p. 259–264.
16. Middlehurst B.M. A Survey of Lunar Transient Phenomena.—*Physics of the Earth and Planetary Interiors*, 1977, Vol. 14, No. 3, p. 185–193.
17. Robinson J.H. Possible causes of LTP.—*Journal of the British Astronomical Association*, 1986, Vol. 97, No. 1, p. 12–13.
18. Steckling F. We Discovered Alien Bases on the Moon. Vista: G.A.F.International, 1990.
19. Vallee J., Vallee J. Challenge to Science. Chicago: Henry Regnery Company, 1966.
20. Wilkins H.T. Flying Saucers from the Moon. London: Peter Owen, s.a.
21. Wilson D. Our Mysterious Spaceship Moon. London: Sphere Books, 1976.
22. Wood R.M. The Extraterrestrial Hypothesis Is Not That Bad.—*Journal of Scientific Exploration*, 1991, Vol. 5, No. 1, p. 103–111.

EDITOR: **Vladimir V. Rubtsov**
RIAP
P.O.Box 4684
310022 Kharkov-22
UKRAINE